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# CARTOGRAPHIC DATA RETRIEVAL, ANALYSIS, DEPICTION, PRESENTATION AND PRODUCT GENERATION: SPECIFICATIONS AND STANDARDS

## Approaches to spatial data base transfer standards

Submitted by the International Cartographic Association**

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## INTRODUCTION

Since the middle of the 1960's various individuals, groups and organizations in many countries in the world have been building various kinds of cartographic databases to use with their cartographic software systems to analyze and display their data. In the early years this work was uncoordinated and somewhat haphazard, but as the years progressed it came to be realized that great efficiencies could be gained if the cartographic database built by one group could be used by another on a system that is different from the originating system. It has been further realized that more efficiencies could be gained if transfer standards could be developed that would facilitate transfers of cartographic databases.

This idea has arisen in many cartographic and spatial data processing groups and organizations in the 1980's where groups have been working on this problem for some years. Other groups and organizations have become interested in the challenge of this problem more recently. As this work was initiated in various countries, research workers began to informally compare notes and experiences concerning such developments. A number of informal discussions have been held at the last few International Cartographic Association technical meetings. During the ICA congress in Morelia, Mexico, in 1987 under the Commission on Advanced Technology under the leadership of Dr. Eric Anderson, the topic was formally examined and discussed.

From those meetings the ICA Working Group on Digital Cartographic Database Exchange Standards was founded in early 1989 by Prof. Harold Moellering of the U.S.A. The following goals were established by Prof. Moellering for the Working Group (WG):

1) The WG will be organized in the 1989 time period;

2) The initial meeting of the WG will be held at the ICA meetings in Budapest in August, 1989.

3) To exchange information and reports by the ICA member countries concerning the development of digital cartographic data exchange standards;

4) To collect and distribute in the WG copies of all standards published in ICA countries;

5) To serve as a focal point of information concerning digital cartographic data exchange developments throughout the world;

6) To identify research needs that arise from the standards process;

7) A presentation by each member of the WG will be made at the Budapest meetings concerning cartographic standards activities in his/her member country.

An effort was made to contact the ICA countries that were engaged in or interested in such work to nominate a member for the WG. International organizations that were known to be working on this problem were invited to nominate an observer to the WG. The idea was to have a member or observer to represent each active ICA nation and international organization in the world.

The founding meeting of the Working Group was held at the ICA technical meetings in Budapest, Hungary in August, 1989. Representatives from 16 ICA countries were present for this meeting. At this meeting many WG members gave presentations concerning the status of cartographic database transfer standards in their country. At this meeting in Budapest, the WG also added an eighth goal, that of producing an ICA monograph that discusses the present state of development of such standards in the various ICA countries and organizations throughout the world. That desire has resulted in this monograph coming into existence. Since the meetings in Budapest the members of the Working Group have been working diligently to produce their chapters. The WG met in Switzerland in July, 1990 to review their draft chapters and to do the final polishing on them. You see the results of their diligent efforts before you.

This monograph is organized into an introduction by the editor that provides the background for this effort. It also provides an explanation of some of the important concepts that underlie this effort, as well as a discussion of the transfer process itself. This preliminary material is important to the reader can more clearly understand the individual standards efforts. This introduction also contains a brief review of each following chapter to succinctly encapsules each effort in a larger context. It concludes with a brief summary of this introductory material. Following that are about 20 substantive chapters that presents the efforts going on in each country and organization represented. This presents a comprehensive picture of the cartographic database transfer standards development efforts that are active throughout the world. In one or two cases groups invited to write chapters did not complete them.

As one reads these individual descriptions of the activities of

these standards developments in the ICA countries and other organizations, it is possible to get the impression that all of the theoretical details are completely understood. This is far from the case. Rather there are many theoretical concepts that are incompletely understood or in some cases, not well at all. These situations provide a number of interesting research opportunities, as described in Moellering (1991b).

## BASIC CONCEPTS

In order to efficiently understand the transfer process and following discussions, it is crucial to clearly comprehend the fundamental cartographic theory that underlies this work. They are the notions of real and virtual maps, deep and surface cartographic structure, and the notion of cartographic data levels. These concepts, and many others, are emerging from the developing area of analytical cartography, which is major thrust to develop a more theoretical and mathematical basis for cartographic concepts. A brief review of analytical cartography has recently been written by Moellering (1991a).

The first major concept of interest here is that of real and virtual maps. During the early 1970's there arose many cartographic products such as CRT images and digital terrain models that went beyond the conventional definition of a map as a fixed hard copy product. These developments resulted in calls to expand the definition of what constituted a map. This dilemma was crystallized by Morrison (1974) in the lead article of the first issue of the American Cartographer where he recognized this growing problem and called for an expanded definition of what constitutes a map. Moellering was faced with the same problem and took up the challenge issued by Morrison. After a few years of research the concept of real and virtual maps was proposed (Moellering, 1980).

It turns out that there are two crucial characteristics that differentiate conventional hard copy maps from other kinds of virtual maps. The first is whether the product can be directly viewed as a cartographic image. Conventional maps and CRT images can be seen that way, but cartographic data files and things like Fourier transforms cannot. They must be transformed to a state that has direct viewability first. The second crucial characteristic is whether the product has a permanent tangible reality. Figure 1 shows a four class diagram that shows the resulting classes of real and virtual maps that are generated by yes/no answers to the two characteristics. The definitions for these classes (Moellering, 1980) are as follows:

> Real Map - is any cartographic product which has a directly viewable cartographic image and has a permanent tangible reality (hard copy). There is no differentiation as to whether that real map was produced by mechanical, electronic means.

| PERMANENT TANGIBLE REALITY | DIRECTLY VIEWABLE AS A CARTOGRAPHIC IMAGE: YES | DIRECTLY VIEWABLE AS A CARTOGRAPHIC IMAGE: NO |
|---|---|---|
| YES | **REAL MAP**<br>Conventional Sheet Map<br>Globe<br>Orthophoto Map<br>Machine Drawn Map<br>Computer Output Microfilm<br>Block Diagram<br>Plastic Relief Model | **VIRTUAL MAP-TYPE 2**<br>Traditional Field Data<br>Gazeteer<br>Anaglyph<br>Film Animation<br>Hologram(stored)<br>Fourier Transform(stored)<br>Laser Disk Data |
| NO | **VIRTUAL MAP-TYPE 1**<br>CRT Map Image<br>a) refresh<br>b) storage tube<br>c) plasma panel<br>Cognitive Map (two-dimensional image) | **VIRTUAL MAP-TYPE 3**<br>Digital Memory(data)<br>Magnetic Disk or Tape(data)<br>Video Animation<br>Digital Terrain Model<br>Cognitive Map (relational geographic information) |

Figure 1. The Four Classes of Real and Virtual Maps

Virtual Map - Type I - has a directly viewable cartographic image but only a transient reality as has a CRT map image. This is what Riffe called a temporary map. Given the direction of current scientific work, electrocognitive displays may be possible.

Virtual Map - Type II - has a permanent tangible reality, but cannot be directly viewed as a cartographic image. There are all hard copy media, but in all cases these products must be processed further to be made viewable. It is interesting to note that the film animation adds a temporal dimension to the cartographic information.

Virtual Map - Type III - has neither of the characteristics of the earlier classes, but can be converted into a real map as readily as the other two classes of virtual maps. Computer-based information in this form is usually very easily manipulated.

Here it can be seen that conventional cartographic products such as sheet maps, atlases, and globes that have a fixed tangible reality, and are directly viewable as a cartographic image are called Real Maps. The other three classes lack one or both of the two characteristics and are called Virtual Maps. These three classes provide for the expanded definition of maps that reflects many of the developments in modern cartography. It turns out that Virtual Maps can contain the same information as a Real Map, and in the case of a cartographic database, perhaps more. Moellering recognized that even cartographic databases should be considered maps because they can contain the information of a Real Map and can be transformed into one if necessary. This solution solves the dilemma recognized by Morrison.

It turns out that the information in these various classes of Real and Virtual Maps can be transformed from one to another as shown in Figure 2.

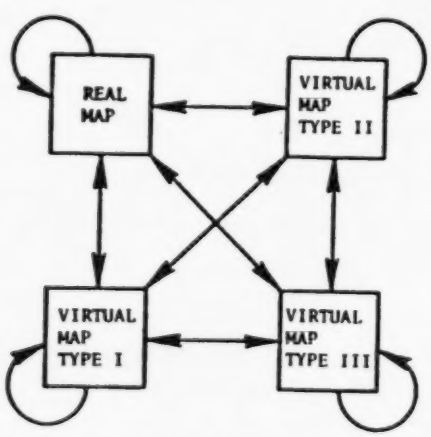


Figure 2. The 16 Real/Virtual Map Transformations

Expanding on a notion pioneered by Tobler (1979), transformations between the four classes of Real and Virtual Maps can be used to define all of the important data processes in cartography. As shown in Moellering (1984) these 16 transformations define operations such as digitizing (R --> V3), CRT display (V3 --> V1), making a CRT hard copy (V1 --> R), direct plotting (V3 --> R), or data base transfer (V3 --> V3). These transformations can also be used to design cartographic systems (Moellering, 1983) and can also be used to define the field of cartography itself (Moellering, 1987).

The second major concept is that of deep/surface cartographic structure developed by Nyerges in his dissertation (1980). Surface structure is defined as the graphic realization of cartographic information and when realized in a fixed hard copy form is called a Real Map. Following the precepts of Noam Chomsky in structural linguistics, Nyerges realized that there was a direct spatial analog to the linguistic deep structure. Cartographic deep structure is the set of spatial entities, attributes and relationships between them that may or may not be graphically realizable. This information is always in a virtual state and is usually found in Virtual Map Type 3 databases. Figure 3 shows this relationship graphically where the lower part of the figure, the surface

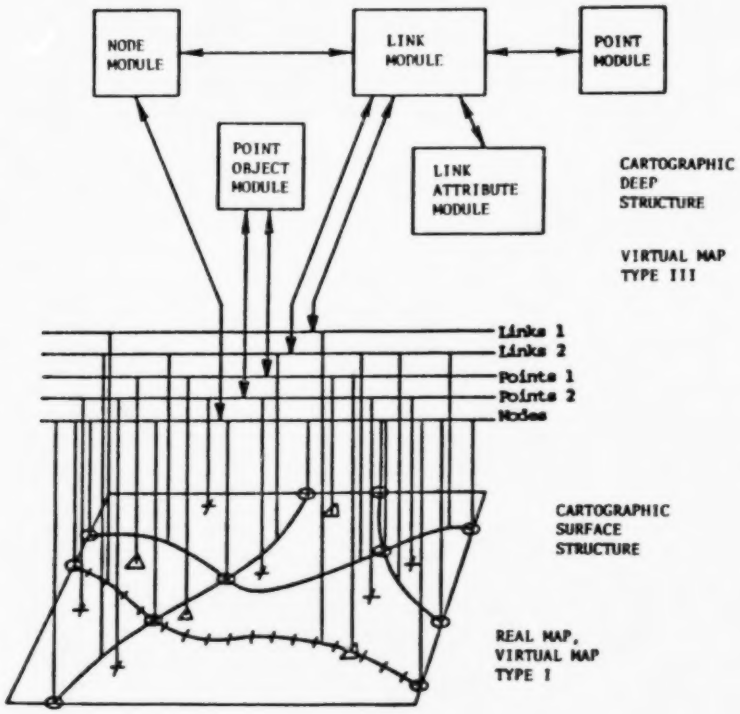


Figure 3. Deep and Surface Cartographic Structure

structure made up of Real Maps and Virtual Maps Type 1, is the area where traditional cartography has been focused for the many centuries of its long and glorious history. However, in the last decade, a new area has been identified, deep structure made up of Virtual Maps Type 3, that is now the focus of an expanding area of analytical work. Deep structure contains work on spatial data structures, analytical operators, fractals just to name a few. For a fuller discussion of analytical map use, see Nyerges (1991). This concept is introduced here because cartographic database transfers are really Virtual Map Type 3 deep structure transfers. More explanation and discussion will follow in a later section.

This concept greatly expands our understanding of cartography and directly reinforces the concept of virtual maps. It can also be seen that analytical cartography largely operates in the area of deep structure and displays its results in a surface representation of some kind, many times in the form of Virtual Map Type 1 CRT images.

The third major concept of importance here is that of Nyerges data levels (1980) which define the levels of spatial data from the most general level of Data Reality to the most specific level of Machine Storage as the bits and bytes are contained in computer hardware systems. The following table lists these levels and provides a short description of them.

Table 1. Nyerges Data Levels

1) Data Reality - The real world and data pertaining to it concerning cartographic entities and relationships between them.

2) Information Structure - A formal model that specifies the organization of information pertaining to a specific phenomenon. It includes data classes and relationships between them and acts as a skeleton for the canonical structure.

3) Canonical Structure - A data model representing the inherent structure of a data set which is independent of specific applications and systems which manage such data.

4) Data Structure - A logical data organization designed for a particular system in which specific relationships and links are implemented.

5) Storage Structure - A specification of how a particular data structure is stored in data records in a particular system.

6) Machine Encoding - The physical representation of how the structure is held in the physical devices of computer system hardware.

It turns out that early developments in cartographic data structures many researchers tried to define the Data Structure, Nyerges

Level 4, directly without having defined the more general levels of the Information Structure and the Canonical Structure first. The Information Structure is a formal model of the information to be housed and managed in the spatial database, while the Canonical Structure is a model of the data to be coded, structured and housed in the database. The Data Structure is dependent on those two more general levels if it is to be efficiently defined. The Data Structure is then stored in data records in the Storage Structure which is physically stored as bits and bytes in the computer hardware in Nyerges Level 6. This work suggests why so many spatial data structures of the 1970's did not work very efficiently or in some cases failed outright. Hence, this concept is crucial to understand in order to clearly see what is involved in the cartographic database transfer process.

## THE DATABASE TRANSFER PROCESS

At the outset, one might conceive of this cartographic database transfer process as capturing and moving a Real Map image from one system to another. In this view such a transfer would be a surface structure transfer. However, the cartographic world is a far richer place than that. The cartographic information to be transferred must first be organized into a Virtual 3 deep structure database. This is because such a Virtual 3 deep structure organization allows for the addition of more deep structure information which is associated with the database, but is not of a surface structure (graphic) nature. Such deep structure information can include a wealth of attribute information, for example, that may be used in the database for analytical purposes and not necessarily for graphic rendering. The key idea here is that such a database transfer between systems is a deep structure Virtual 3 transfer and not a surface structure transfer. A deep structure transfer facilitates building the transfer file itself as well as the restructuring of the data itself into the spatial data structure of the system to which the database is being transferred. One must realize that when cartographic or spatial data is in a Virtual 3 deep structure form, it is much more flexible and manipulable than it would be in other states.

At this point it is important to understand the difference between the use of pairwise converters for database transfers, the current situation, and the use of a more general metafile transfer, the proposed situation for most national transfer standards. One issue involves the number of database converters that would be required to do the job. Suppose that there are 100 cartographic systems with heterogeneous data structures, software systems and hardware architectures in an open systems environment that are candidates for transferring spatial databases among them. Using the current situation of pairwise data converters as an example one would need

$$\frac{n(n-1)}{2} = \frac{100(99)}{2} = \frac{9{,}900}{2} = 4{,}950$$ pairwise converters

to accomplish the transfer between all combinations of systems. The desired situation is to have a common metafile transfer

standard that can be used for (almost) all database transfers where 2 n + = 2 (100) = 200+ metafile converters would be required to accomplish the task. It can be clearly seen that the metafile transfer approach is preferred because in theory about 200 metafile converters would be required, whereas 4,950 pairwise converters would be required. This is a tremendous difference. In practice this difference would probably be smaller because in the pairwise case not all combinations would require implementation, and in the metafile case converters would probably be required for general classes of spatial database systems. But even if three times more metafile converters were required, 600 in this example, and only 60 percent of the pairwise converters were required, the difference would be about 3,000 converters for the pairwise case and 600 for the metafile case. This is still a five to one savings for the metafile approach. That is why national standards groups are moving towards this solution for their database transfer requirements. For the long run, the metafile approach is clearly preferred.

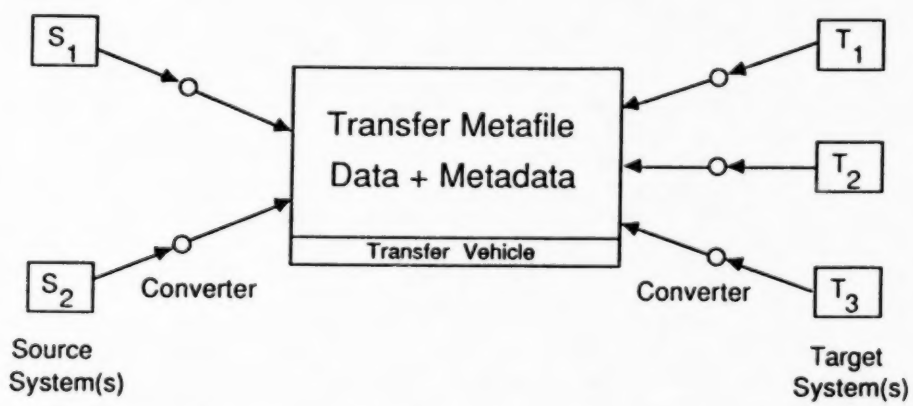


**Figure 4. The Cartographic Database Transfer Process**

Figure 4 shows an illustration of the general cartographic database transfer process. On the left is the Source Database with its own information structure, canonical structure, and data structure, data elements and modules. On the right are several Target Databases to which one desires to transfer the cartographic database. These cartographic databases are associated with different systems that may have very different data structures and hardware architectures. Therefore the source data structure usually cannot be transferred directly between the two systems. It is usually necessary to take the source database and convert it into the organization of the Transfer Metafile. This conversion is done by a software converter designed for that purpose that reads the data structure of the Source Database and converts it into the structure of the Transfer Metafile.

The Transfer Metafile has a structure that is specified by the national standard for which it was designed. This Transfer

Metafile is the actual vehicle that carries the data from the Source to the Target systems. The internal structure of various national transfer standards differ widely in approach and design. They range from fairly straightforward formats to fairly rich transfer mechanisms. This will be discussed later. Many national Transfer Metafiles have as their base an international transfer standard such as ISO 8211 or others to act as base transfer vehicle. This vehicle facilitates the actual mechanics of the transfer.

When the Transfer Metafile arrives at the Target System, it must be converted from the organization of the transfer file to that of the target system(s). This is accomplished by a converter that reads the Transfer Metafile and converts the structure of the data to that of the Target System. That system itself will then insert the actual data into its database.

One question that arises from the above description is what kinds of data components can be transferred with such a process. Fundamentally, one has descriptions of features from the real and attributes associated with them, cartographic objects that contain the geometry and topology of the features, information on the data quality, and other essential information such as projection, coordinate system, etc. The features have been defined by the individual national groups and code such things as mountains, streams, transportation, cities, soil, population and a host of other things that exist in the real world. Associated with these features are a set of attributes that contain information about those features such as mountain elevations, stream flow, transportation type, city name, soil type, population components, and so on. The cartographic objects usually have a set of primitives that begin with the level of spatial dimension, 0-, 1-, 2-, 3-, etc., and may contain information about topological properties of the object, such as connectivity or contiguity (neighbor relation). Quality information that relates to the above features, attributes and objects is specified and carried along with the transfer. Depending on how this information is specified, this quality information could relate to large classes of data, or to individual features or objects themselves. Ancillary information such as projection, coordinate system is usually part of the transfer file and serves an important role in processing the data. Finally, some standards include metadata, which is data that relates to the substantive data being transferred, to aid in the transfer process. Such metadata can be particularly helpful to the decoding converter that receives the Transfer Metafile and converts into the structure of the Target System. The nature of this metadata varies greatly between the various national transfer standards. This above discussion also implies that each national standard has specified things like feature definitions, object definitions, quality levels, and the Transfer Metafile organization itself.

The Transfer Process and Data Models

The database transfer process can also be examined from the point of view of the data model(s) involved. At the conceptual level it

involves the Information Structure, Nyerges level 2, and the Canonical Structure, Nyerges level 3, while at the operational level it involves the Data Structure, Nyerges level 4 and the Storage Structure, Nyerges level 4. The Information Structure is a model that describes how the entities from the real world that are contained in the database are related one to another. In order for a database transfer to take place effectively, the source database and the target database must be compatible with one another. For example, if the source database only contains information pertaining to roadway systems and the target database only information pertaining to streams and waterways, a data transfer is not feasible because the source and target databases are not compatible with each other. If, on the other hand, the target database contains data on streams, waterways, roadways, and communication linkages, then a transfer from the source to the target database is feasible. Therefore, at the information structure level, when the subject matter of the source and target databases is compatible, a transfer between them is usually feasible, assuming that the lower Nyerges levels are compatible too.

One can now look at the Canonical Structure, Nyerges level 3, which specifies the model of the <u>data</u> that is contained in a database. At the outset one must be clearly aware that there are three general families of data structures that are specified by such data models. They are vector, raster and relational. These are treated as distinct classes of data organization which are not compatible with one another. Therefore, it is not feasible to attempt to transfer data from a source database that has some sort of raster structure to a target database that has some sort of vector structure. Going between these three families of spatial data organization is a data conversion problem beyond the sort of spatial data transfer problem being discussed here. Since this discussion focuses on the data transfer question, such conversions between the three families of spatial data will not be further considered here. It is therefore assumed that database transfers of the kind being discussed here will be transfers <u>within</u> each of these three fundamental families of spatial data. However, with some of the national efforts, it is possible and feasible to transfer data from these three families within different sections of a transfer file. In that case raster data from the source system would arrive as raster data at the target system, vector from the source system would arrive at the target system as vector data, and so on. No conversions between families could be made. The intriguing question as to whether there may exist a unified theory of spatial data that would permit more general data models and structures has been raised and discussed in Moellering (1991b).

The data model specifies the formal organization of the spatial data for a particular system. When transferring data between two systems that have the identical data model, even when there are differences in the implementation of the Data Structure, Nyerges level 4, the transfer is straightforward. This current discussion is setting aside the question of hardware architecture differences

for the moment, which will be discussed later. The more typical case is when the data models in the source and target systems are different, even though they are in the same data structure family. The general answer to this question is that if the source and target systems contain the equivalent information, even though it may be structured in differing data models, a data transfer can usually be carried out. However, there are limitations to this possibility. For example, if the source system data model contains geometry and topology for the fundamental cartographic objects, and the target system data model only contains geometry for such objects, the transfer can be made, although it will be an information losing transfer. However, if the source system data model only contains geometric information on the cartographic objects, and the target system data model contains both geometry and topology, then a problem arises because the target system requires information that is not found in the source system. Since the data transfer tools described below are not designed to generate new information for the target system, such a transfer cannot be carried out. Therefore, the general principle to be learned here is that these kinds of data transfers can be information losing, although it is inefficient to do so, but they cannot be information gaining.

One can then consider the specifics of the Data Structure, Nyerges level 4. It is very common for large differences to exist between Data Structures in the source and target systems even though the data models may be fairly similar. Obviously large differences will exist between the two Data Structures when the data models are also very different. Assuming that the information contained in the source and target systems are equivalent, the transfer process must restructure the data so it is compatible with the target system when they arrive at that end of the process. The transfer process must also overcome differences at the Storage Structure level, Nyerges level 5, as well. There will almost always be large differences between the Storage Structures of the source and target systems due to differences of the operating system and hardware architecture differences. These kinds of differences are not inconsequential and must be properly handled by the transfer process.

Transfer Machinery

One can now begin to turn to the machinery that actually carries out the data transfer. It turns out that the various national standard proposals differ considerably in approach and outlook to this problem. This section provides a conceptual framework of the range of the kinds of transfer machinery that is being proposed in the field. In all cases such transfer machinery must accomplish two major tasks:

1) It must transfer spatial data from source to target system where there are differences between the data models, data structures, and storage structures of the two systems, as discussed above;

2) It must transfer the spatial data in such a way that the process transcends differences in hardware architecture between the source and target systems.

This second requirement is just as important as the first. Every transfer standard must address this question. In general, approaches to the problem range from using a fairly fixed format to using one of the international standards such as ISO 8211 or EDIFACT as a basic implementation vehicle.

Reflecting back to Figure 4, every standard has a transfer file. Those that are more rigid transfer the information in the form of a fairly rigid data model. As the transfer standard becomes more flexible the data model reflected in the transfer file becomes more flexible. The most flexible form of transfer standard can be called a transfer mechanism. Here the transfer data model is a very flexible minimal model that can accommodate a wide range of source/target data models. This range of approaches to the problem can be conceptually viewed as a continuum as illustrated in Figure 5. At the extreme left one has the system specific fixed data

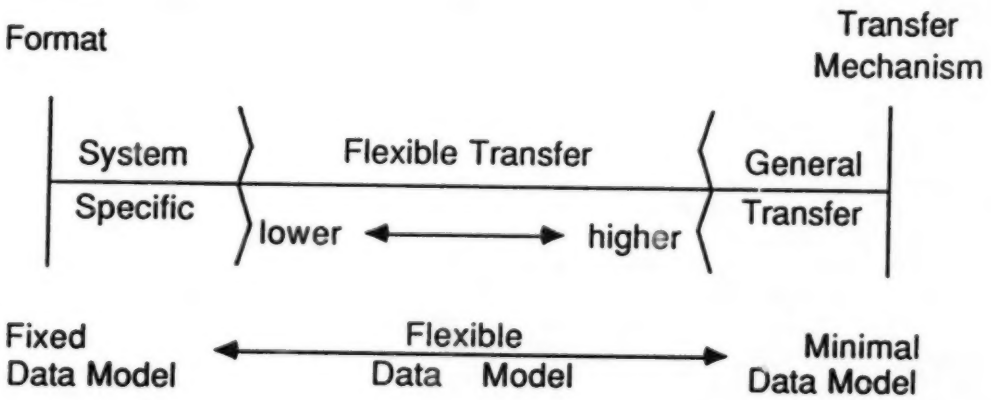


Figure 5. The Range of Cartographic Database Transfer Processes

model that would be a fixed fairly rigid format. If the source and target systems were the same fixed data model used by the transfer standard, the data transfer would be very simple. However, this level is very inflexible can generally cannot accommodate a wide range of other data models for transfer. It would have fairly limited use between differing systems. Few if any of the national standards proposals are this rigid. More likely is the case where the transfer standard has a its own fairly specific data model that has been designed to accommodate a wider range to source and target data models. These more flexible data formats are more widely applicable to the situation where there are wider differences between the source and target data models. These systems require that the source data model be converted into the transfer data model which is then later converted into the target system data model. This also implies conversions in the data structures and file structures

as well. The more flexible is one of these transfer formats, the wider range of source and target data models that can be accommodated. However, this implies increasing complexity of the standard as the flexibility of the format increases. The most flexible kind of a transfer standard tends toward a very flexible data model that is almost minimal in nature. It focuses on a modular primitive object design where the transfer structure is organized around the source data model in such as way that the transfer structure can be decomposed and reconstituted later as the target data model. This sort of transfer standard can be called a transfer mechanism. At the extreme such a transfer mechanism would have a very minimal data model that can be structured to accommodate an extremely wide range of source/target data models. As the range of the flexibility of such a transfer mechanism increases, the complexity of the mechanism would also increase as well. The goals here would to design a mechanism that maximizes flexibility and minimized complexity. Since these goals conflict and are tradeoffs one with another, the task of designing a national transfer standard that serves the professional community efficiently is not an easy one.

## DESIRED CHARACTERISTICS OF THE TRANSFER PROCESS

As one looks at this sort of spatial data transfer process, it is possible to identify basic characteristics that such a process should possess. The following discussion provides a listing and brief definition of the desirable characteristics that such a process should have. It is based on an earlier discussion by Moellering (1988) and has been adapted to the more general international situation. The discussion will be carried out in terms of general characteristics, cartographic objects, data quality, cartographic entities, and finally the transfer machinery.

Transfer Three Major Families of Spatial Data Structures

Currently there exist three major families of spatial data structures. A successful database exchange process should be able to transfer vector, raster and relational data structures and associated ancillary information.

Transfer Across Different Computer Architectures

For proprietary reasons there are many different kinds of internal machine architectures for computers. Many of these architectures are not compatible with each other. A good spatial database transfer mechanism will be able to transcend such architectural differences.

Transfer Databases Between Noncommunicating Parties

Typical database exchanges require prior communication, documentation and sometimes extensive discussion before any data can be transferred. The goal is to specify the standard such that this kind of communication is not necessary, but is built in as part of a standard data exchange mechanism.

Modular and Extendible
Because of the dynamic developments in the field of cartography and spatial data structures, the standard must be specified in a modular fashion. In this way new developments which need to be included in the future can be added in a modular fashion without disturbing other parts of the standard. Obsolete parts could be deleted in a similar way.

Robust and Reliable
Any database exchange mechanism must be specified such that it is robust and reliable. This means that it must not be sensitive to some data errors and occasional data corruption such that data perishability during transmission should be very low, thus insuring that the probability of correct transmission is quite high.

Media Independent
The exchange mechanism should be media independent such that spatial databases can be transferred by magnetic tape, direct telecommunication, hard or floppy disk, CD/ROM or any other appropriate medium.

Transfer Both Syntax and Semantics
A good transfer process with the above characteristics should be able to exchange the syntax, or structure of the data reasonably straightforwardly. However, the capture of the semantics, or meaning of the information transferred is much more difficult to insure. Transfer of the semantics is more difficult to do than is the transfer of syntax.

Facilitate the Transfer of Self-Describing Databases
Currently such databases are experimental or only a gleam in the designer's eye. However, it is clear that such databases are being developed and that they will be in common use within a decade. A standard must accommodate such exchanges.

Use Best Concepts and Existing Standards Available
Developing an efficient and comprehensive spatial database transfer standard in not a simple matter. Therefore one must be clearly aware of current research such that the best available concepts are used in the design of the standard. The items presented in the conceptual background form the crucial intellectual basis of a standard. Existing national and international standards that apply to the problem must be sought out and examined. Such existing standards should be utilized whenever possible.

Awareness of Work in cognate Areas
Every discipline such as cartography has interactions with its cognate areas, and therefore one must be aware of what is going on in those areas in the way of standards activities. In this case one must pay attention to four primary cognate areas: geographic and land information systems, photogrammetry and remote sensing, computer graphics and CAD/CAM, and, geodetic and land surveying.

Involve the User Community in the Process
This is a very important and time consuming activity. However, it is crucial because as the scientific solution to the standard is developed, a consensus must be developed in the professional community it is intended to serve.

Maintenance Authority
Developing cartographic standards is NOT a one time process. Since such a standard is being built in an area such as spatial data, there is active research taking place in many areas. One must realize that periodically the standard will have to be updated in the future. Therefore, it is clear that the initial effort must be conducted such that future enhancements can be made without disturbing the existing parts of the standard. Hence, the notions of modularity, extendibility and robustness become very important so that the standard can be enhanced as new developments take place. All of this implies the founding of a maintenance authority to supervise the interpretation of the standard and to lead the work of actual maintenance. It is expected that the area with the highest demands on maintenance will be the cartographic entities.

## CARTOGRAPHIC OBJECTS

Cartographic objects are the digital representation of entities and as such are the fundamental building blocks of any spatial data structure. Hence, they must be modular, and be capable of being assembled into more complex and higher dimensional structures.

Only Necessary to Define Primitive and Simple Objects
As with any standard, one must always clearly define the primitives in the system. Here it was also necessary to define some simple objects that are constructed out of primitives from lower dimensions. These simple objects serve as the primitive objects for the higher dimensions.

0-, 1-, 2-, and 3- Dimensional Objects Should be Defined
All four levels of dimensional primitives should be specified with provisions for building higher level objects if they become necessary. The standards currently do not explicitly define anything above 2-D primitives because not enough is known about them at the present time. 3-D and higher dimensional objects can be added as a future enhancement as they are better understood and needed by the community.

Geometry and Topology
When defining cartographic objects, it is necessary to define them so they include aspects of geometry and topology. How this is done can vary greatly depending the nature of the particular national standard being defined.

Coordinate Systems
For a spatial data standard objects must be validly defined for both Euclidean and simple curved surfaces such as the sphere and

the ellipsoid.

Modular and Extendible Object Set
Given the above object requirements and general characteristics it is clear that the set of primitive and simple objects must be modular such that new ones, 3-D for example, could be added in the future, and so that compound and complex objects can build out of them.

## DATA QUALITY

Data quality is an essential ingredient to any database transfer because the integrity of the data must be insured throughout the exchange process.

Truth in Labeling
The fundamental rubric under which the data quality portion of the standard operates is truth in labeling. This means that the producer of the database should be required to provide specified quality information for review by the prospective user. The user would review the quality report and decide whether that particular database is suitable for a particular application. It is anticipated that the better quality databases will see more frequent use than those of lesser quality and hence the specification of the quality report will create a tendency towards creating databases with improved data quality.

Flexible Quality Levels
In order to function as a national standard with broad application, it is clear that a national must have flexible quality levels in it. Fixed quality levels are product specific and therefore outside of a national standard, but may exist as internal quality specifications for particular products produced by individual organizations.

Various Levels of Testing Rigor
Because of the flexible quality requirements that are necessary, there are also different levels of testing rigor that could be applied in a particular situation. However, the report should explicitly state which level has been applied and what the results are.

## CARTOGRAPHIC ENTITIES

Cartographic entities exist in the real world and are the things being represented modeled, analyzed and displayed in modern cartographic work.

Universal Set of Entity Definitions
The set of entity definitions for a national standard are desired to be universal and encompass all entities that may be coded in spatial databases at the national level. However there is a bottom limit of interest in detail for a national standard. A standard should be designed with conceptual hooks on the bottom to which

additional entities and attributes could be attached.

Modular Entity Definitions
Entities are defined in a modular fashion with many aliases of analogous terms linked to them. This will serve to simplify the structural complexity of the definitions themselves, and pave the way for a nonheirarchical definition structure for the entities, if desired.

Extendible Set of Entities
Because of the modular definitions of the entities, a maintenance authority could update and modify the entity set as a regular and systematic part of its work.

Scale Independent These entity definitions are designed to be scale independent and not related to product specific scales. This is because a database may be used at a range of scales for various purposes, within reason.

Nonhierarchical Definition Structure
It is possible to define a set of entity definitions that are that are not hierarchically organized. Hierarchical entity definition structures are cumbersome to use, subject to judgmental error and are not very amenable to modern query retrieval systems. Therefore, an entity can be defined with many possible attributes and attribute values that could be assigned depending on the situation of the actual entity in the real world.

Designed for Modern Query Retrieval Systems
With the modular definitions, scale independence, and nonhierarchical definitional structure, entities, their associated attributes, and attribute values can be easily entered, retrieved and manipulated in modern database query management systems.

## THE TRANSFER MACHINERY

The transfer machinery is what actually can convert the source data base to the transfer metafile form and later decode the metafile into the target database. The transfer metafile is the exchange file that is actually transferred between computer systems. This kind of transfer can occur with magnetic tape, by direct telecommunication, with hard or floppy disk, CD/ROM or almost any other kind of form because a standard should be media independent as pointed out earlier.

Transfer Three Families of Data and Ancillary Information
The data exchange mechanism should be designed to transfer data bases from all three of the fundamental data structure families: vector, raster, and relational, as well as information pertaining to attributes of the entities and associated quality information.

Modular Forms and Modules
Each of the three families of data structures should have a modular

transfer form associated with it. Each of these three forms should be composed of a set of modules that transfer the primitives, attributes, quality information, and other ancillary information. Every module of this kind is composed of a set of records that describe its own contents.

Preserve Syntax and Semantics
In the database transfer between systems, the syntax is preserved in the logical forms and modules. However, the semantics, or meaning, is implicitly preserved in the syntax of the exchange. Clearly, the syntax of the information is easier to preserve than the semantics.

Minimize External Documentation
A good database exchange process will reduce the need for external documentation, particularly if the software is written to run interactively. Ultimately, such a standard should be designed with the concept of being able to support self-describing databases in the future when they become available.

Generate Export Database Metafiles
The transfer converter processes the information from the source database and creates an exchange metafile for the actual database transfer between systems as shown in Figure 4. The transfer metafile will then be decoded into the target database by the converter.

Conform to Existing Standards
A particular standard must usually conform to existing national standards. In addition, International Standards Organization (ISO) standards should be used whenever practicable. These are the same or similar to existing standards used in other countries.

## OVERVIEW OF STANDARDS EFFORTS

Currently there are about 20 ICA member nations and other international organizations working on the question of spatial database transfer standards. This work contains chapters that describe 18 of those efforts that are in progress. The range of these efforts includes those that are in the beginning stages of examining the problem to those that are nearly finished with a comprehensive effort. The following discussion summarizes each effort for which a written chapter has been received.

Australia
Work on a national topographic data transfer standard began in Australia in 1974, a very early effort. The effort focused on developing a transfer format for map data that was codified in 1981 as AS 2482 Interchange of Feature Coded Digital Mapping Data by Standards Australia. The standard was revised in 1984. In the later 1980's the group realized that a more comprehensive database transfer standard was needed. The groups are now evaluating their effort as well as the work of several of the ICA national groups.

Currently the U.S. Spatial Data Transfer Standard (SDTS) is a leading candidate for adoption. Further evaluation is proceeding.

Austria

Although digital map data processing has been going on for many years in Austria, it is only recently that an initial database transfer standard has been proposed by the Austrian Standards Institute. This standard is called ÖNORM A 2260, 1990 Datenschnittstelle für den Austausch geographisch-geometrischer Plandaten (Interface for digital exchange of geographic-geometrical data). This data transfer format is oriented primarily towards large scale maps and drawings. As such it currently geometry only with topology not explicitly specified. Since the standard was proposed in 1990, it has not yet been extensively field tested.

Canada

Canada is in the interesting position of developing more than one spatial database transfer standard, the first in the topographic area, and the second in the hydrographic area. The first effort began in the late 1970's by the Canadian Council of Surveying and Mapping (CCSM), now called the Canadian Council on Geomatics (COG). They have developed a Standard for the Exchange for the Exchange of Digital Topographic Data which was originally proposed in 1982. The proposed standard is a variation of a flexible format, and includes a data model, standard features and attributes, a quality specification, and a file format. Implementation and testing of the standard commenced in 1986. The standard is in its later stages of approval.

The second major effort in Canada is that of Map and Chart Data Interface Format (MACDIF) proposed by a group of agencies in the country. Work began in 1985 and is progressing. The MACDIF syntax is based on the Abstract Notation Syntax (ASN) and is intended "to standardize the interface point between two communicating entities regardless of the mapping or charting application".

Work is also going on to develop a Geographic Document Architecture (GDA). This effort is intended to operate is an Open Systems Interconnection (OSI) environment.

Peoples Republic of China

The challenge of cartographic database transfer is seen as a component of Geographic Information System (GIS) standardization in the Peoples Republic of China. Work is in the early stages of defining the problem in this context. It includes projects to develop land classification codes, creation of 1:4M geographic database, computerization of topographic symbols, among others.

Finland

Work on database transfer has been going on in Finland since the 1970's. In 1985 the Ministry of Agriculture and Forestry established a steering committee on the LIS project. The practical part of this work is being carried out by the National Land Survey. This work has resulted in National Administrative Standards (VHS) VHS

1041 on Geographical Data Representation and VHS 1040 on Message Description. These standards operate in an EDIFACT (ISO 9735, Electronic Data Interchange For Administration Commerce And Trade) environment. As such these data transfer standards seem to be a fairly flexible transfer mechanism. Additional work has been carried out on a Geographical Data Dictionary System (GDDS), a geographical query language that is a subset of SQL, as well as an EDIFACT interpreter.

France

Work on a national transfer standard in France was initiated by the National Council for Geographic Information (CNIG) in 1987. This led to a Commission for the Normalization of Exchange Formats. This group has been working on the database transfer standard in the areas of data model, data definition, exchange files, and exchange of messages. This has led to the adoption of the DIGEST data model (see DIGWG below) implemented on an ISO 8211 base that is called EDIGEO. Testing is in progress.

Federal Republic of Germany

The effort in the Federal Republic of Germany was begun in the early 1970's by the Working Committee of the Surveying and Mapping Institutes of the Länder (AdV). In 1982 the Uniform Database Interface (EDB) was published. This work has now become involved with the development of the Authoritative Topographic Kartographic Information System (ATKIS). As part of this work a data model, feature catalog and symbol catalog have been defined. As such EDBS appears to be a relatively fixed format. Current work is being carried out to define a more flexible version of EDBS in cooperation with other European efforts, notably CERCO.

Hungary

In the later part of the 1980's digital cartographic data processing became more widely spread and the need for a database transfer standard was realized. Initially efforts were made to review the Canadian, American, British and German standards proposals. Further work has resulted in a proposal for a Digital Cadastral Map standard (DCM). Work on this effort is continuing.

Japan

Although digital cartography has been used in Japan for many years, it is only relatively recently that standardization efforts have been actively pursued. In 1985 the Geographical Survey Institute formed the Committee for Digital Mapping Standardization. This group defined the Standard Procedure and Data Format for Digital Mapping in 1988. This specification includes data quality, a feature coding system, and transfer format. As such this transfer standard is a somewhat flexible format based on fixed length records.

New Zealand

In 1987 Land Information New Zealand (LINZ) began closely evaluating possible alternatives for a spatial database transfer standard. After careful study, the U.S. Spatial Data Transfer Standard (SDTS)

has become a leading candidate for adoption. However, LINZ is developing attribute definitions for use in the country. Further work is continuing.

Norway
In the late 1970's the Norwegian Ministry of Environment initiated the SOSI (Coordinated Approach to Spatial Information) project. From this project arose a defined transfer format, SOSI, in 1985. Object definitions and attribute codes were defined in 1987. The SOSI format is specified at four levels of use and as such is reasonably flexible. An ISO 8211 implementation vehicle is being considered. Currently SOSI only handles vector data, but future plans include handling raster and pictorial data.

South Africa
In 1985 a project team was formed at the CSIR Centre for Advanced Computing and Decision Support to develop a national spatial data exchange standard for South Africa. In 1987 SWISK 45 was published and has now become known as the National Exchange Standard (NES). NES provides for the transfer of vector and raster data. As such it is implemented by a relational transfer format that seems to be rather flexible. Current work on NES includes further enhancement of the standard and producing a user manual.

Sweden
In the early 1980's the Swedish Association of Local Authorities developed a simple standard, KF85, for the transfer of vector data. Since 1986 an effort has been under way by the Research & Development Council for Land Information Technology (ULI), to define a more comprehensive data transfer standard. Several Working Groups are carefully evaluating standards being developed in other countries. Currently, primary interest is focusing on an adaptation of the British NTF format on an ISO 8211 implementation that is compatible with the German ATKIS system in cooperation with CERCO.

Switzerland
The Swiss are currently developing a cadastral data system that will use a data transfer format called AVS (Amtliche Vermessungs Schnittstelle). They are also evaluating other national efforts to develop such data exchange standards. There is interest in the possibility of adapting one of these standards as it applies to the situation in Switzerland. Evaluations are continuing.

United Kingdom
In 1983 the House of Lords Select Committee on Science and Technology recommended that a set of map data exchange standards should be established to replace earlier, more limited work. In 1986 the first version of the National Transfer Format (NTF) was issued. It is a reasonably flexible format that can transfer vector data with both geometry and topology. Raster and grid data can also be accommodated. NTF is specified on 5 levels of operation and transfers information on features and data quality. Current work involves evaluating the possibility of using ISO 8211 as the base

implementation mechanism for NTF.

United States
The need to develop a comprehensive cartographic data transfer standard became evident in the early 1980's. To this end the ACSM National Committee for Digital Cartographic Data Standards was founded in 1982 under the sponsorship of the U.S. Geological Survey. Shortly thereafter the Federal Interagency Coordinating Committee for Digital Cartography was founded in 1983. Through their cooperative efforts The Proposed Standard of Digital Cartographic Data was published in 1988. Further work by the USGS Technical Review Board refined what is now known as the Spatial Data Transfer Standard (SDTS). SDTS is a very flexible exchange mechanism that will transfer vector, raster and relational data. Digital cartographic objects that have a wide variety of geometric and topological properties can be transferred. The standard consists of an object specification, entity specifications, data quality information, and the transfer mechanism. SDTS uses ISO 8211 as the basic implementation vehicle. SDTS has been extensively tested and is currently undergoing its final evaluation and polishing on its way to becoming a Federal Information Processing Standard (FIPS).

Comité Europeen des Responsable de la Cartographie Officielle
CERCO is an organization composed of the directors of the European national cartographic agencies. As such CERCO is interested in the possibility of defining a European Transfer Format (ETF). The leading contender seems to be a modification of the British NTF format adapted to an ISO 8211 implementation base. Discussions are continuing.

Digital Geographic Information Working Group
DGIWG is an international group with members of several European countries including the United States and Canada that was formed in 1983. Most of these countries are NATO members, although the DGIWG leadership has stated that this effort is independent of NATO. DGIWG has recently produced a proposal for a data transfer format called DIGEST, which is intended to handle raster, vector and matrix data. Digest is being amended to run on an ISO 8211 implementation base. A feature and Attribute Coding Catalog (FACC) has also been produced, along with several specifications for raster products. Field testing of DIGEST is continuing.

## SUMMARY AND CONCLUSIONS

As the reader can see, there are currently many cartographic database transfer efforts going on in many parts of the world. The ICA Working Group on Cartographic Database Exchange Standards was founded in order to provide a forum for discussing this work at the international level.

In order to really understand the data transfer process, it is very important to understand the key concepts involved, such as real and

virtual maps, their transformations, deep and surface cartographic structure, and the six Nyerges data levels. With those basic concepts in hand, one can begin to more fully understand the database transfer process. It is clear that the transfer metafile approach has advantages over the conventional pairwise converter approach because of the dramatically fewer number of data converters that would be necessary to specify, build and maintain.

It can be seen that it is possible to design and build a variety of cartographic database transfer processes that range from a simple fixed format that has rather limited use, to a more flexible format that has a much wider scope of use, to an exchange mechanism that can transfer most data organizations within the three data structure families in an environment that is hardware independent. These characteristics, plus many more discussed above provide the specifications for an ideal spatial data transfer mechanism.

Finally, one can review the large number of national efforts to develop such standards as discussed in the following chapters of this monograph. It can be seen that there is a very wide range of activities going on from some groups that are evaluating the situation to groups that have been working on the problem for many years and are in the final stages of a major transfer standard effort.

The question can also be raised concerning the future of this work, and the Working Group specifically. Clearly there is much more work to be done to continue dialogue between these various groups as the work continues. It is also possible to begin work to make comparisons between the standards being developed and proposed. It is possible that commonalities between the various transfer standards can be identified with the possibility of developing interlinkages between some of them. The question of a world standard has been raised, but this kind of a goal seems very elusive indeed. It seems possible that some of the standards could be adopted on a regional basis for common benefit. However, much more effort is required before this question can be efficiently answered.

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